

Description

RECORDING METHOD, RECORDING APPARATUS, AND STORAGE
MEDIUM

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Technical Field

The present invention generally relates to a recording method, a recording apparatus, and a storage medium in which optimum recording power is determined by performing test writing on a test zone of a recording medium, and information is recorded on the recording medium by using the determined optimum recording power.

Background Art

For example, Japanese Patent Application Publication No. 2003-22532 (hereafter called patent document 1) discloses a technology with which, in recording information on a second or subsequent recording layer of a multilayer optical disc having a multi-recording-layer structure, laser power of a recording laser beam can be adequately controlled and information can be recorded with excellent recording quality even when the amount of passing light varies depending on recording conditions of a recording layer situated closer to a laser source than the target

recording layer. The laser beam from the laser source is focused on the surface of a recording film of the optical disc by an optical pickup, and reflected light is detected by a light detecting unit and input into a control unit to perform power control of a laser driver. Before starting recording of user data, the control unit determines a recording power by performing tests of recording power on a recording power testing zone outside of a user data recording zone. The control unit records user data on the user data recording zone based on the determined recording power.

Disclosure of Invention

Problems to be Solved by the Invention

When information is recorded on a conventional single layer recording medium having only one recording layer, the optimum laser power for recording differs depending on conditions such as differences among recording apparatuses, recording speed, and characteristics of recording media. For this reason, test writing is performed on a certain test zone for the optimal power control (OPC) for determining the optimal laser power for recording before writing or rewriting information. The OPC should also be performed when writing or rewriting information on a recording medium

with a multi-recording-layer structure (multilayer recording medium), which has multiple recording layers within one recording surface.

When recording information on such a
5 multilayer recording medium, there are problems as described below.

1. For example, when information is recorded on the second recording layer of a two-layer recording medium having two recording layers within one recording
10 surface, the information must be recorded on the second recording layer through the first recording layer. Therefore, the amount of light of a laser beam reaching the second layer differs depending on whether information is recorded (the layer having high
15 reflectivity and low transmittance) or not recorded (the layer having low reflectivity and high transmittance) on the first layer. As a result, optimum recording power varies depending on the condition of the first layer. This fluctuation in optimum recording power may result
20 in lower recording quality of the second layer, represented by jitter, high error rates, or the like.

2. When information is to be recorded on a recordable or rewritable multilayer recording medium in which test zones in the first and second layers are
25 positioned so as not to overlap, the optimum recording

power for recording information on the first layer can be obtained by performing the OPC in its test zone. After information is recorded on the first layer, the first layer has low reflectivity and high transmittance.

5 Information should be recorded on the second layer through this first layer. Since the test zone in the second layer is positioned so as not to overlap the test zone in the first layer, no information is recorded on the portion of the first layer through which test
10 writing for the second layer is performed. Therefore, the state of the portion is different from that of another portion of the first layer through which information is to be actually recorded.

3. Also, even when the test zones in the
15 first and second layers are positioned in the same recording surface area and the OPC is performed in the test zone in the second layer, if the first layer test zone which is in the same recording surface area as that of the second layer test zone is in an erased state, the
20 state of the first layer test zone is different from that of the other zones of the first layer through which information is actually recorded.

An object of the present invention is to determine the optimum recording power for recording
25 information on the second or subsequent layer of a

multilayer recording medium by performing test writing.

Means for Solving the Problems

A recording method according to the present invention determines an optimum recording power value by performing test writing on a test zone of a recording medium and records information on the recording medium with the determined optimum recording power, where the recording medium is a multilayer recording medium having multiple recording layers within one recording surface; a test zone is formed on each recording layer; and when information is to be recorded on a target recording layer that is second or further from a light source, information is recorded on a portion, which is positioned in a same recording surface area as that of the test zone, of an upper recording layer that is closer to the light source than the target recording layer before the test writing is performed on the test zone in the target recording layer.

A recording apparatus according to another aspect of the present invention, which determines an optimum recording power value by performing test writing on a test zone of a recording medium and records information on the recording medium with the determined optimum recording power, where the recording medium is a

multilayer recording medium having multiple recording layers within one recording surface and a test zone is formed on each recording layer, includes a preprocessing unit which, when recording information on a recording layer that is second or further from a light source, records information on a portion, which portion is positioned in the same recording surface area as that of the test zone in the target recording layer, of an upper recording layer that is closer to the light source than the target recording layer; and a test writing unit which, after the recording on the upper recording layer, performs the test writing on the test zone of the target recording layer.

According to still another aspect of the present invention, a computer-readable storage medium has a program recorded therein for causing a computer, which makes a recording apparatus determine an optimum recording power value by performing test writing on a test zone of a recording medium and record information on the recording medium with the determined optimum recording power, where the recording medium is a multilayer recording medium having multiple recording layers within one recording surface and the test zone is formed on each recording layer, to function as a preprocessing unit which, when recording information on

a recording layer that is second or further from a light source, records information on a portion, which portion is positioned in the same recording surface area as that of the test zone of the target recording layer, of an upper recording layer that is closer to the light source than the target recording layer; and to function as a test writing unit which, after the recording on the upper recording layer, performs the test writing on the test zone of the target recording layer.

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Advantageous Effect of the Invention

With the present invention, the optimum recording power for recording information on the second or subsequent layer of a multilayer recording medium can be obtained.

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Brief Description of the Drawings

FIG. 1 is a drawing illustrating a configuration of a multilayer recording medium;

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FIG. 2 is a block diagram illustrating electric connections in a recording apparatus;

FIG. 3 is a drawing used to describe a process of detecting upper and lower envelope levels with AC coupling;

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FIG. 4 is a drawing used to describe the OPC;

FIG. 5 is a flowchart illustrating a process performed by the recording apparatus;

FIG. 6 is a flowchart illustrating another exemplary process performed by the recording apparatus;

5 FIG. 7 is a flowchart illustrating another exemplary process performed by the recording apparatus;

FIG. 8 is a drawing illustrating another configuration of a multilayer recording medium;

FIG. 9 is a flowchart illustrating another
10 exemplary process performed by the recording apparatus;

FIG. 10 is a flowchart illustrating another exemplary process performed by the recording apparatus;

FIG. 11 is a drawing used to describe the process shown in FIG. 10;

15 FIG. 12 is a flowchart illustrating another exemplary process performed by the recording apparatus;

FIG. 13 is a drawing used to describe the process shown in FIG. 12;

FIG. 14 is a flowchart illustrating another
20 exemplary process performed by the recording apparatus;

FIG. 15 is a drawing illustrating inner (a) and outer (b) drive areas in a multilayer recording medium; and

FIG. 16 is a block diagram illustrating a
25 recording medium on which a program is recorded.

Explanation of References

	101 Recording apparatus
	107-1 CPU
	107-2 ROM
5	107-3 RAM
	108 Memory unit
	109 External I/F
	120 Host computer
	130 Storage medium
10	201 Multilayer recording medium
	202, 203 Recording layer
	202a, 202b Data zone
	202b, 202c, 203b, 203c Test zone
	202b, 202e Portion
15	301, 302 Count zone

Best Mode for Carrying Out the Invention

The best mode for carrying out the invention is described based on the following embodiments with
20 reference to the accompanying drawings.

1. First Embodiment

A preferred embodiment of the present invention is described below. FIG. 1 is a drawing
25 illustrating a configuration of a multilayer recording

medium 201 used in this embodiment. The multilayer recording medium 201 is a multilayer recording medium having multiple recording layers within one recording surface (this exemplary recording medium has two layers:
5 a first layer 202 and a second layer 203). Examples of such a multilayer recording medium are an optical disc and a magnetic optical disc which enable optical recording and playback of information.

The first layer 202 and the second layer 203
10 of the multilayer recording medium 201 includes data zones 202a and 203a; and test zones 202b, 202c, 203b, and 203c in the inner and outer disc areas, which are used to perform the OPC for determining optimum laser power for recording. Each pair of the test zones 202b
15 and 203b and the test zones 202c and 203c are positioned so as not to overlap with each other within the same recording surface of the multilayer recording medium 201.

FIG. 2 shows a configuration of a recording apparatus 101 which controls the optimum recording power
20 of a laser and records information on the multilayer recording medium 201.

A recording medium D such as the multilayer recording medium 201 is rotated by a rotary motor 114 which is a drive source. The rotary motor 114 is
25 controlled by a disc rotation control unit 102 and

rotates at a specified speed.

A head 103, with focusing and tracking servos provided by a servo unit 104, focuses a laser beam and forms recording marks on a recording film of the recording medium D. Also, the head 103 is movable along the radius of the recording medium D and can access the test zones and data zones provided in the recording medium D.

The head 103 is equipped with a light source (not shown). For the light source, a laser diode (LD) is normally used. The laser is modulated by an input pulse signal from an LD driver 112 to achieve a specified recording power level. By modulating the laser between a recording power level and a space power level, recording marks and spots without recording marks are formed on the recording film. This results in differences in reflectivity and enables the reproduction of information signals.

When the recording medium D is a write-once medium such as a DVD-R or a DVD+R using organic dye, recording marks are called pits and other spots are called space.

A power setting unit 111 drives the LD driver 112 according to recording power instructions input from a controller 107 for centralized control of the

recording apparatus 101, and makes the laser emit light at the specified power. During the OPC, the power setting unit 111 goes into a test-writing mode and sequentially changes the recording power.

5 Data to be recorded on the recording medium D are encoded or modulated by a data generating unit 113 into a specified format and output in a serial format as a data string.

 The pulse width may be fixed at a certain
10 value. However, it is preferable to set the pulse width by using the controller 107 according to linear velocity and disc types. By doing so, it is possible to compensate for the differences in sensitivity among recording mark lengths caused by the differences in
15 linear velocity and disc types.

 The type of a recording medium D is detected by decoding playback signals generated when a certain portion of the disc is played back by the head 103. If identifying makers of recording media D is possible in
20 some way, those makers may be used as types of recording media D. Also, it is more preferable to divide each maker type into sub-types. For the identification of types, for example, various parameters pre-embedded in recording media D may also be used. For example, if
25 recommended power and pulse width are embedded, those

parameters may be used for identification.

Also, a unique maker identification code (vendor code) for each maker may be embedded. Further, codes for sub-types may also be embedded. Those codes
5 enable optimum pulse width setting (write strategy) depending on various recording films of each maker.

Next, test writing, or the optimum power control (OPC) is described.

In the test writing, information is recorded
10 at a fixed linear velocity and by sequentially changing the recording power, the recorded portion is played back to evaluate the recording quality, and the recording power which produces optimum recording quality is determined.

15 The recording apparatus 101 shown in FIG. 2 can sequentially change the recording power through the power setting unit 111 according to instructions from the controller 107 while recording information. If the recording medium D is a multilayer recording medium 201,
20 test writing is performed on the test zones 202b, 202c, 203b, 203c shown in FIG. 1.

After test writing on one of the test zones, playback signals (RF signals) are obtained by playing back the recorded portion with the head 103. Optimum
25 recording quality is determined by evaluating certain

parameters of the RF signals. For example, a β -value detecting unit 106 measures a parameter β .

The β -value detecting unit 106 removes (with AC coupling) low-frequency components of the RF signals and detects upper envelope level a and lower envelope level b. This process is described with reference to FIG. 3. Assume that, as the characteristics of a recording film, the reflectivity of recording marks is low, and the level of RF signals is low in spots with low reflectivity. When the recording quality is normal, the upper and lower sides of AC-coupled RF signals are symmetric ($a = b$) as shown in FIG. 3 (a). When the recording power is too high, recording marks become long, and the upper side level of AC-coupled RF signals becomes higher than the lower side level ($a > b$) as shown in FIG. 3 (b). When the recording power is too low, recording marks become short, and the lower side level of AC-coupled RF signals becomes higher than the upper side level ($a < b$) as shown in FIG. 3 (c).

β is obtained by normalizing the difference between a and b by the RF amplitude ($a + b$). In other words,

$$\beta = (a - b) / (a + b)$$

A large β value indicates that the power is too high; a small β value indicates that the power is

too low. The optimum power is indicated by a certain β value (for example, around 4%). This β value is called a β target. In the OPC, information is recorded by sequentially changing recording power, β values for the
5 recorded portion are evaluated, and the recording power at the β target is obtained.

FIG. 4 shows the relationship between the power and β values. In FIG. 4, 10 levels of recording power are used for recording. The range of recording
10 power levels is called the OPC range and the central power level is called Pdef and used as the standard level. The OPC range may be +40% and -30% from Pdef and divided into 10 levels. The OPC range may also be +5 mW and -4 mW from Pdef where the power level is
15 incremented/decremented by 1 mW.

The β curve is drawn using the obtained 10 β values which curve forms a (two-dimensional) approximation and the power Popc which corresponds to the β target is obtained. Popt may fluctuate depending
20 on the conditions such as temperature change when the OPC is performed. Therefore, in normal conditions, Popc should preferably be obtained at a point as close to Pdef as possible. Also, since Popc varies depending on recording media D, in many cases, Popc is set along with
25 a write strategy corresponding to each type of the

recording media D. For a memory unit 108, a non-volatile memory may be used. The memory unit 108 stores OPC power correction parameters for each recording apparatus 101.

Next, an exemplary process of performing the
5 OPC for the multilayer recording medium 201 is described with reference to a flowchart shown in FIG. 5.

For example, when information is recorded while rotating the multilayer recording medium 201 at a constant linear velocity (CLV), the relative velocity
10 between the multilayer recording medium 201 and the laser beam for recording is always constant. Therefore, once optimum recording conditions such as recording power and recording pulse width are determined, those conditions can be used for the entire multilayer
15 recording medium 201.

The OPC is performed in the inner and outer disc test zones 202b, 203b, 202c, and 203c by using various recording power levels. Then, information is recorded at a constant linear velocity on the entire
20 recording medium by using the determined optimum recording power.

As shown in FIG. 5, when information is recorded on the first recording layer 202, the controller 107 performs, in the same way as recording
25 information on a single-layer recording medium D, the

OPC in the inner disc test zone 202b and determines the optimum recording power (step S1). Information is recorded on a data zone 202a in the first recording layer 202 by using the determined optimum recording power (step S2). When information recording on the first layer data zone 202a is completed (Yes in step S3), the optimum recording power for the second recording layer 203 should be determined before recording information on the second recording layer 203. In this case, the recording states of the second layer test zone 203b and the first layer data zone 203b which is situated closer to the laser source than the second layer data zone 203a on which information is actually going to be recorded are different.

15 In other words, the first layer test zone 202b and the second layer test zone 203b are positioned so as not to overlap within the same recording surface. The portion (202d in FIG. 1) of the first layer which is situated closer to the laser source than the second layer test zone 203b is in the erased state (high reflectivity and low transmittance). On the other hand, information has already been recorded on the data zone 202a of the first layer which is situated closer to the laser source than the second layer data zone 203a on which information is going to be recorded. The first

layer data zone 202a is in the recorded state (low reflectivity and high transmittance).

Therefore, the optimum recording power is not obtainable with the current state of the portion 202d.

5 To obtain the optimum recording power, the state of the portion 202d should be changed so as to conform to the actual recording state. To match the laser beam transmittance to the second layer test zone 203b with that to the second layer data zone 203a, information is
10 recorded on the portion 202d of the first layer which is in the same recording surface area as that of the second layer test zone 203b and is closer to the laser source than the test zone 203b (preprocessing unit) (step S4).

After step S4, the optimum recording power is
15 determined by performing the OPC in the second layer test zone 203b (test writing unit) (step S5), and then data are recorded on the second layer data zone 203a (step S6).

FIG. 6 is a flowchart illustrating another
20 exemplary process. In this process, the controller 107 determines the optimum recording power for each of the first and second layers by performing the OPC in the first and second layer test zones 202b and 203b before recording data on the first layer data zone 202a (steps
25 S1, S4, and S5). After these steps, the controller 107

records data on the first and second layer data zones 202a and 203a in sequence (steps S2, S3, and S6).

Either one of the processes shown in FIG. 5 and FIG. 6 may be used for recording. However, since the laser characteristics change due to the temperature change at the end of recording on the first layer data zone 202a, the process in FIG. 5, in which the recording power for the second layer is determined after recording on the first layer is completed and just before starting recording on the second layer, is more preferable to determine the optimum power.

As shown in FIG. 1, also in the outer disc area of the multilayer recording medium 201, first and second layer test zones 202c and 203c are positioned so as not to overlap in the same recording surface area. Therefore, the above description is applicable when performing the OPC in the outer disc test zones 202c and 203c. In step S4 for this case, information is recorded on a portion 202e of the first layer which is in the same recording surface area as that of the test zone 203c.

In still another case, information may be recorded on the second recording layer 203 regardless of whether recording information on the first recording layer 202 is completed or not. The process in such a

case is described with reference to a flowchart shown in FIG. 7. In this process, if recording information on the first layer data zone 202a has already been completed (Yes in step S3), the controller 107 performs test writing on the second layer test zone 203b after recording information on the portion 202d of the first layer (steps S4 through S6). If information is not recorded on the first layer data zone 202a (No in step S3), the controller 107 performs test writing on the second layer test zone 203b without recording information on the portion 202d of the first layer (steps S5 and S6).

2. Second Embodiment

Another embodiment of the present invention is described below. FIG. 8 is a drawing illustrating a configuration of a multilayer recording medium 201 used in this embodiment. In FIG. 8, a detailed description of reference letters corresponding to those for the multilayer recording medium 201 shown in FIG. 1 is omitted. The multilayer recording medium 201 shown in FIG. 8 differs from that shown in FIG. 1 in that test zones 202b and 203b and test zones 202c and 203c are positioned in the same recording surface area of the multilayer recording medium 201. Therefore, unlike the

multilayer recording medium 201 shown in FIG. 1, a portion 202d of the first layer which is closer to the laser source than the second layer test zone 203b and a portion 202e of the first layer which is in the same recording surface area as that of the test zone 203c do not exist in the multilayer recording medium 201 shown in FIG. 8.

The hardware configuration of a recording apparatus 101 used to record information on the multilayer recording medium 201 is the same as that of the recording apparatus 101 shown in FIG. 2. In the description below, the same reference letters as in FIG. 2 are used and detailed description of those reference letters is omitted.

Next, a process performed by the recording apparatus 101 is described.

FIG. 9 is a flowchart of a process in which the recording apparatus 101 performs the OPC for the multilayer recording medium 201 and starts recording data.

First, the controller 107 determines whether the recording is for the second layer or the first layer based on the addresses in the write command (step S11). If the recording is for the first layer, the controller 107 performs the OPC in the first layer test zone 202b

or 202c, and determines the optimum recording power (step S15). Then, the controller 107 sets the determined optimum recording power and records (writes) information on the data zone 203a of the multilayer recording medium 201 (step S14).

If the recording is for the second layer (Yes in step S11), the controller 107 records information in advance, with the optimum recording power used for recording on the first layer, on the first layer test zone 202b or 202c which is in the same recording surface area as that of the second layer test zone 203b or 203c (step S12). After this recording is finished, the controller 107 performs the OPC in the second layer test zone 203b or 203c which is in the same recording surface area as that of the recorded test zone 202b or 202c, and determines the optimum recording power (step S13). The recording apparatus 101 sets the determined optimum recording power and records (writes) information on the second layer data zone 202a of the multilayer recording medium 201 (step S14).

With the process described above, the optimum recording power for recording on the second layer can be correctly obtained.

Next, another process performed by the recording apparatus 101 is described.

FIG. 10 is a flowchart of a process in which the recording apparatus 101 performs the OPC for the multilayer recording medium 201 and starts recording data. In FIG. 10, steps corresponding to the steps in
5 FIG. 9 have the same reference letters and detailed description of those steps is omitted.

In the process as shown in FIG. 10, if the recording is for the second layer (Yes in step S11), the controller 107 records information before test writing
10 on the second layer test zone, with the optimum recording power used for recording on the first layer, only on a portion of the first layer test zone 202b or 202c required to perform test writing once (step S16). Then, the controller 107 performs the OPC in the portion
15 of the second layer test zone which is in the same recording surface area as that of the portion of the first layer test zone 202c which is used to perform the test writing once (step S13). In an example shown in FIG. 11, only a portion 202c1 of the first layer test zone
20 202c is used to perform the test writing once. After data are recorded on this portion, the OPC is performed only in a portion 203c1 of the second layer test zone 203c which is in the same recording surface area as that of the portion 202c1.

25 Next, still another process performed by the

recording apparatus 101 is described.

FIG. 12 is a flowchart of a process in which the recording apparatus 101 performs the OPC for the multilayer recording medium 201 and starts recording data. In FIG. 12, steps corresponding to the steps in FIG. 9 have the same reference letters and detailed description of those steps is omitted.

In the process as shown in FIG. 12, if the recording is for the second layer (Yes in step S11), the controller 107 determines whether information has been recorded on the first layer test zone 202b or 202c which is in the same recording surface area as that of the second layer test zone 203b or 203c (step S17). If information has been recorded (Yes in step S17), the OPC for the second layer is performed in the corresponding zone, and the optimum recording power is determined (step S18). If information has not been recorded (No in step S17), the controller 107 records information in advance, with the optimum recording power used for recording on the first layer, on the entire first layer test zone 202b or 202c which is in the same recording surface area as that of the entire second layer test zone 203b or 203c (step S19). Then, after recording on the first layer test zone is completed, the controller 107 performs the OPC for the second layer in the second

layer test zone which is in the same recording surface area as that of the first layer test zone on which information has been recorded, and determines the optimum recording power (step S18). In an example shown
5 in FIG. 13, the controller 107 records information in advance, with the optimum recording power used for recording on the first layer, on the entire first layer test zone 202c which is in the same recording surface area as that of the entire second layer test zone 203c.

10 The process described above eliminates the need to record information on the first layer test zone 202b or 202c which is in the same recording surface area as that of the second layer test zone 203b or 203c each time when the OPC is performed in the second layer,
15 thereby reducing the time for the OPC on the second layer.

Next, still another process performed by the recording apparatus 101 is described.

FIG. 14 is a flowchart of a process in which
20 the recording apparatus 101 performs the OPC for the multilayer recording medium 201 and starts recording data. In FIG. 14, steps corresponding to the steps in FIG. 9 have the same reference letters and detailed description of those steps is omitted.

25 In this process, if the recording is for the

first layer (No in step S11), test writing starting address is obtained from the count zone (disc count zone) (301 or 302 in FIG. 15) of the first layer (step S21). Then, the OPC is performed in the test zone 202b or 202c (303 or 304 in FIG. 15) which corresponds to the obtained addresses, and the optimum recording power is determined (step S22). After the OPC is performed, indicator information indicating the test zone used for the OPC is recorded in the count zone 301 or 302 (step S23).

If the recording is for the second layer (Yes in step S11), the controller 107 determines whether information has been recorded on the first layer test zone 203b or 203c which is in the same recording surface area as that of the second layer test zone 202b or 202c by referring to the count zone 301 or 302 (step S24). If information has been recorded (Yes in step S24), the controller 107 performs the OPC in the second layer test zone 203b or 203c, and determines the optimum recording power (step S13).

If information is not recorded (No in step S24), the controller 107 records information in advance, with the optimum recording power used for recording on the first layer, on the first layer test zone 203b or 203c (step S25). After information recording on the

first layer is completed, the controller 107 records the indicator information indicating the test zone 203b or 203c on which information is recorded, in the count zone 301 or 302 (step S26). After the recording on the first
5 layer, the controller 107 performs the OPC in the second layer test zone 202b or 202c which is in the same recording surface area as that of the first layer test zone 203b or 203c recorded in the count zone 301 or 302, and determines the optimum recording power (step S13).

10 With the process described above, it is possible to determine a first layer test zone on which information has already been recorded and to prevent performing test writing in the same first layer test zone.

15 FIG. 16 is a block diagram illustrating a recording medium on which a program is recorded. The processes described above with reference to FIGs. 5, 6, 7, 9, 10, 12, and 14 may be performed by a CPU 107-1 of a microcomputer included in the controller 107 based on
20 a program. The CPU 107-1 loads the programs stored in its storage medium ROM 107-2 or a memory unit 108 into a RAM 107-3 and executes the program.

 The system may also be configured so that a host computer 120 connected through an external I/F 109
25 reads a program stored in its storage apparatus or a

storage medium 130 and controls the recording apparatus 101 based on the program to perform processes shown in FIGs. 5, 6, 7, 9, 10, 12, and 14.

For the storage medium 130 for recording the
5 programs, recording media such as a CD-ROM, flexible disc, and magnetic optical disc which record information optically, electrically, or magnetically; semiconductor memories such as a ROM and a flash memory which record information electrically; and other types of recording
10 media may be used.

The present invention is not limited to the specifically disclosed embodiments, and variations and modifications may be made without departing from the scope of the present invention.